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BRITISH COLUMBIA

Roberts Creek Study Forest: preliminary effects of partial harvesting on peak streamflow in two S6 Creeks

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ABSTRACT

This study investigated the effect of partial logging systems on peak flows in small creeks in the Roberts Creek Study Forest. Two partial logging systems were tested: variable retention (VR) and strip shelterwood.

The analysis followed the paired watershed approach; paired peak flows in the two treatment creeks are compared with those of the control creek, before and after treatment, to detect changes in peak flow that are attributable to logging. A peak flow is defined as the maximum instantaneous flow resulting from an individual storm.

Streamflow data was subjected to regression analysis. Study results indicate that the application of partial logging systems on small creeks results in statistically significant increases in peak flows. The magnitude of the increase is proportional to the forest canopy removed, expressed as a percentage of the watershed area of the creek. The peak flow increases are most consistent for "large" flows above a return interval of 0.5 years. The VR treatment results in a large variability in its effect on peak flow compared with the strip shelterwood treatment. Although there is not yet enough data to show it statistically, there appears to be a difference between the two treatments that goes beyond the proportion of the canopy that is removed. Strip shelterwood appears to result in less extreme increases in peak flows compared with VR treatment, especially with regard to rain-on-snow conditions.

The study results provide evidence to support the use of strip shelterwood or other patch treatments as a means of mitigating against large changes in peak flow, and helping to control the variability of peak flow increases due to rain-on-snow conditions. Although the study was carried out on S6 creeks, the results are relevant to larger creeks such as S2 and S3.

1.0 INTRODUCTION

In spite of the many studies that have been conducted to investigate changes in streamflow following clear-cut logging, the exact nature of those changes in coastal watersheds remains elusive. Changes in total flow volume following forest harvesting have been well documented (e.g., Bosch and Hewlett, 1982; Hicks et al., 1991). However, it is far more difficult to demonstrate changes in peak streamflow due to forest harvesting in coastal watersheds. Early studies by Rothacher (1973) and Harr and McCorison (1979) in the Oregon Cascades reported that the sizes of large peak flows remain largely unchanged by logging. Conditions that generate peak flows are highly variable in coastal watersheds, and include rainfall, rain-on-snow (ROS) and radiation snowmelt. As a result, peak streamflows in harvested watersheds can be either higher or lower than those in adjacent uncut watersheds, depending on antecedent conditions.

It is this large variability in response that has resulted in the inconclusive nature of these studies. Harr (1986) pointed out that since event type

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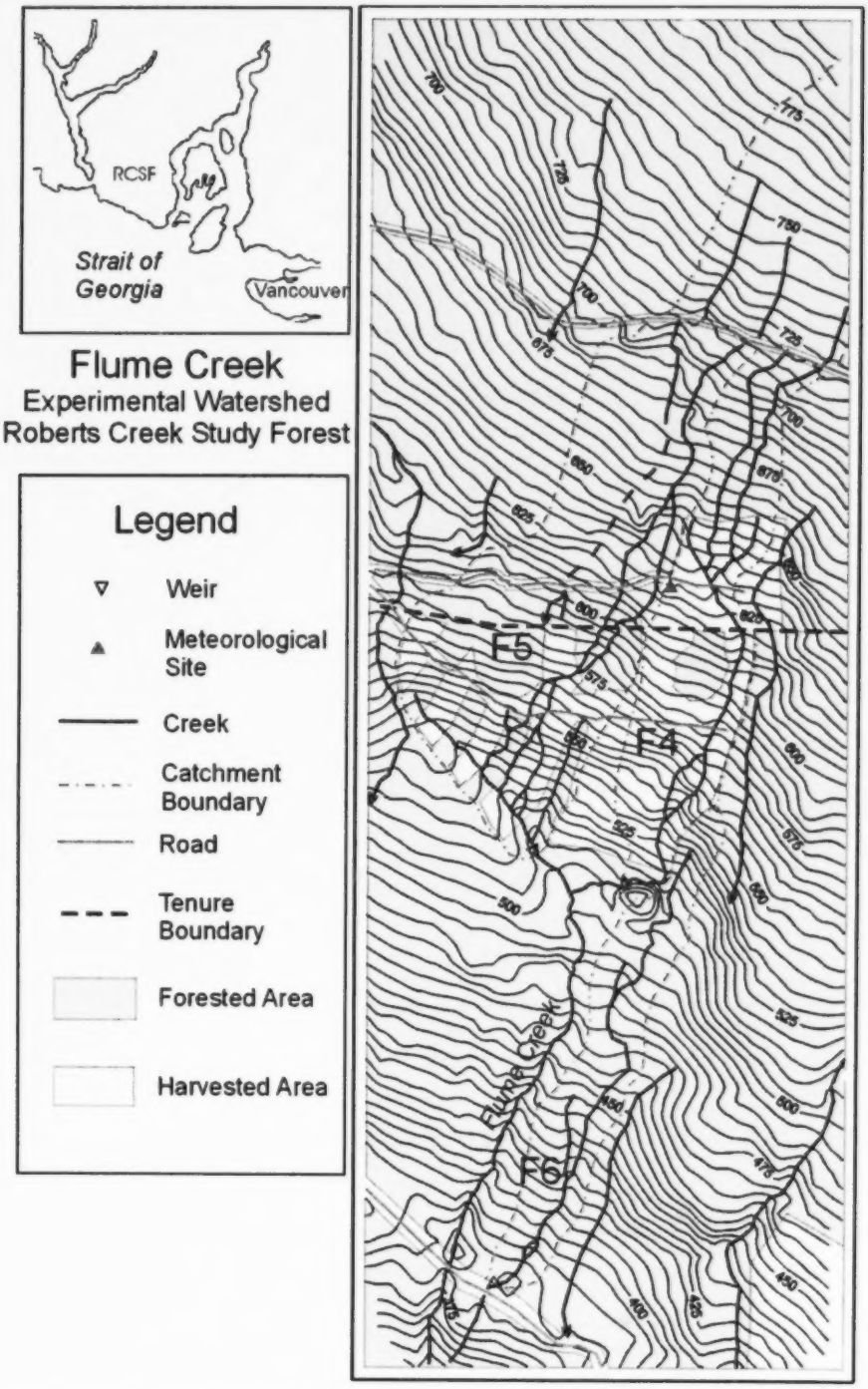

Figure 1: Map of the Flume Creek Experimental Watershed showing forest harvesting treatments as of Spring 2000. The study area is located in the Roberts Creek Study Forest (RCSF) on the Sunshine Coast, BC (see inset).

strongly influences the outcome of any analysis of peak flows resulting from forest harvesting, any such analyses should be based on similar events. For instance, the greatest increases in peak flow in harvested watersheds have been observed due to warm rain on ripe snowpacks.

The issue of whether or not forest harvesting actually affects peak flows has been the subject of much debate in the literature recently. In a highly controversial paper, Jones and Grant (1996) proposed that older studies failed to detect logging-induced increases in peak flow due to inappropriate analytical techniques. In a follow-up paper using the same data, Thomas and Megahan (1998) reported that the analytical methods used by Jones and Grant were inappropriate or incorrectly applied. Both papers agreed that the peak flows that were most affected by logging were the smallest ones, and that as event size (hence return interval) increases, the effect of logging on the size of the peak flow diminishes. Jones and Grant claim that even events with a return interval as large as 50 years are increased by as much as 50% after logging, although Thomas and Megahan suggest that this claim does not appear to be supported by their data or their analysis. They could find no change in peak flow for events with return intervals of greater than 1.5 years. Accordingly, one might then conclude that large peak flows of a magnitude that might be related to stream channel stability or aquatic habitat, such as the 2-10-year event, could be unaffected by forest harvesting.

As a result of the advent of partial logging systems in British Columbia, forest managers are now beginning to ask how such methods affect peak flows, compared with clear-cut logging. The purpose of this paper is to provide some preliminary answers to those questions, based on data obtained from the Flume Creek Paired Watershed Experiment.

The Roberts Creek Study Forest (RCSF) is located on the southwestern flank of Mount Elphinstone on the Sunshine Coast, approximately 40 km northwest of Vancouver, BC (Figure 1). The RCSF is a collection of adaptive management case studies demonstrating a range of cutting patterns in blocks designed to assist the development of future silviculture prescriptions in the lower elevation, naturally regenerated Douglas-fir dominated ecosystem of the southern coast of the mainland. The Flume Creek Paired Watershed Experiment is one component of the RCSF, and was implemented to investigate the effects of two partial harvesting systems on streamflow and water quality in small S5 and S6 creeks.

2.0 STUDY AREA

The Mount Elphinstone slope is relatively uniform and dissected by first-order creeks that drain narrow elongated catchments. The interfluves between these first-order creeks are further dissected by zero-order creeks. A zero-order creek is difficult to identify through the forest cover on air photos, and therefore generally does not appear on maps. It is ephemeral, and does not occupy a clearly defined gully, but nonetheless is capable of carrying very substantial flows (Figure 2). In contrast, first-order creeks are perennial and are clearly visible on air photos because they normally occupy gullies.

The Flume Creek Experimental Watershed consists of three small catchments, designated as F4, F5 and F6 (Figure 1), that are typical of the type of drainage pattern described above. All three creeks are classed as S6 under the Forest Practices Code of BC Act and Regulations. F4 and F6 creeks are zero-order, whereas F5 is a first-order creek at the outlet, with several zero-order tributaries. The zero-order creeks typically go dry in June or July. The first-order channel of F5 usually does not go completely dry, but flow is reduced to an unmeasurable trickle. The creeks do not start to flow again until soil moisture is recharged in the fall; this usually requires several rain storms. For example, in 1996 the creeks did not start to rise until mid October.

F6 drains an area of 16 ha and ranges in elevation from 395 to 560 metres above sea level, with a mean channel gradient of 13%. F4 and F5 range from 505 to about 850 metres above sea level, with drainage areas of 39 and 61 ha respectively. F4 has a mean channel gradient of 17%. The first-order channel of F5 has a gradient of 6.5%, while the zero-order tributaries have an average gradient of 18%. All zero-order channel gradients reflect the local land slope.

S6 creeks are generally not a major concern for forest managers (they do not support fish, and water licenses are usually on larger streams). Nonetheless, S6 creeks were selected for the study in order to carry out a standard paired watershed experiment within the operational forest management strategy of the Sunshine Coast Forest District. Because the target maximum block size is 10 ha., it was necessary to study small catchments to achieve a canopy removal that is likely to produce a measurable effect.

3.0 METHODS

3.1 MEASUREMENT OF STREAMFLOW

Each creek is equipped with a weir for flow measurement (Figure 2). The weirs are constructed of concrete with a plywood wall at the downstream end to which a sharp crested metal weir plate is attached. The weir plate has a central 90° V-notch section to allow for precise measurement of low flows, but also has a rectangular overflow section to accommodate high flows. The V-notch section has a head of about 0.25 metres, and the rectangular section has a head of about 0.5 metres above the V-notch section. At F4 and F5 the weirs were constructed in straight channel reaches, in late summer when the channels were dry. The channels were deepened, and plywood forms were built into which concrete was poured. The plywood was removed after the concrete had dried. At F6 the creek flows into the ditch as it leaves the forest above the road, and from there flows through a culvert. Therefore, instead of setting the weir into the channel, two retaining walls were constructed in the ditch to create a pond. The weir plate is set into one of the walls. Otherwise, the weir was constructed as described above. F5 and F6 were built in September 1994 and F4 in the summer of 1995.

The weirs have been calibrated (Cathcart, 1997) and provide very precise flow measurement based on calibration equations that relate flow to the head of water over the weir crest. Each one is equipped with a staff gauge located at the upstream end of the structure and corrected to the weir crest. At each site, stage is measured with a Unidata capacitive water depth probe and average values are recorded on a Unidata "Macro" 7000 data logger at a log interval of 15 minutes. The resolution of this instrumentation is $\pm 1\%$.

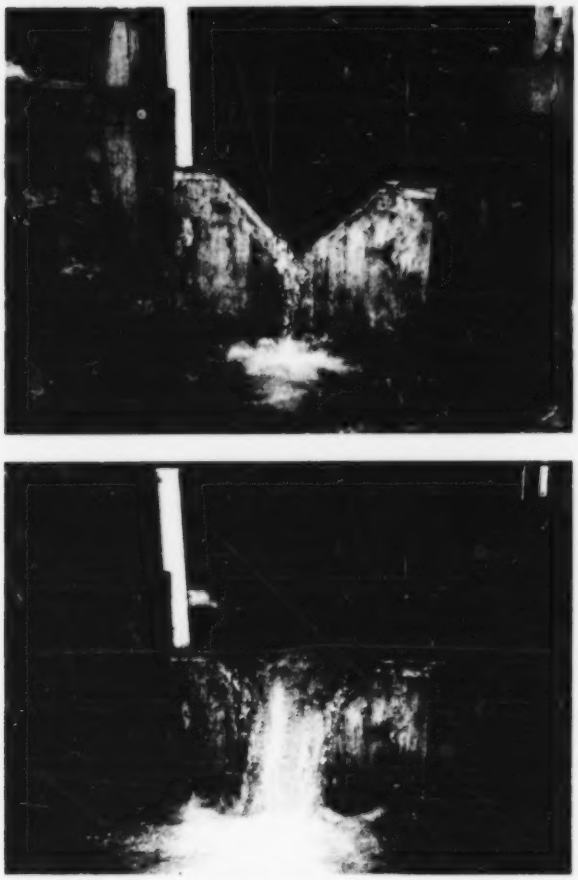

Figure 2: F4 weir at low and medium flow.

3.2. FOREST HARVESTING TREATMENTS

The treatments selected for the experiment were a variable retention (VR) harvest, involving a combination of grouped and dispersed retention, and a strip shelterwood cut. The intent of the treatments is that the strip shelterwood treatment should result in half the canopy removal of the VR treatment, expressed as a proportion of the watershed area. The strip shelterwood treatment was originally laid out as five strips with alternating leave strips of equal width. The VR treatment was applied to F4 and involved 18% canopy retention, not including individual reserve trees. The strip shelterwood treatment, applied to F5, retained 49% of the harvested area in the leave strips (Figure 1).

Forest harvesting treatments were done in two stages, partly due to a forest tenure boundary that divides the catchments into two parts (Figure 1). The lower part of the watershed falls under the Small Business Forest Enterprise Program (SBFEP) managed by the Ministry of Forests, Sunshine Coast District. The upper part lies within private land owned and managed by Canadian Forest Products Limited (Canfor). Harvesting treatments began in the fall of 1998 in the SBFEP portion. At that time, the three upper (i.e., furthest upstream) strips in F5 and the VR treatment in F4 were harvested. Blowdown that occurred in the reserve patches of F4 and in the leave strips of F5 reduced the residual canopy density somewhat. It is estimated that the reduction is in the order of an additional 3–5% of the residual stand. However, as a result of concerns over the stability of the leave strips, the leave strip adjacent to the eastern boundary of F5 was doubled in width, and the lower two cut strips combined into one. This strip was harvested in the summer of 1999. Later that fall, harvesting of the upper part of F4 was completed by Canfor, duplicating the VR treatment that was applied to the SBFEP block.

The harvesting schedule described above resulted in a two-stage canopy removal, such that after Year 1, canopy removal was

Figure 3: Overview of harvesting treatments as of spring 2000. The VR treatment on F4 is on the right, and the strip shelterwood treatment on F5 is to the left.

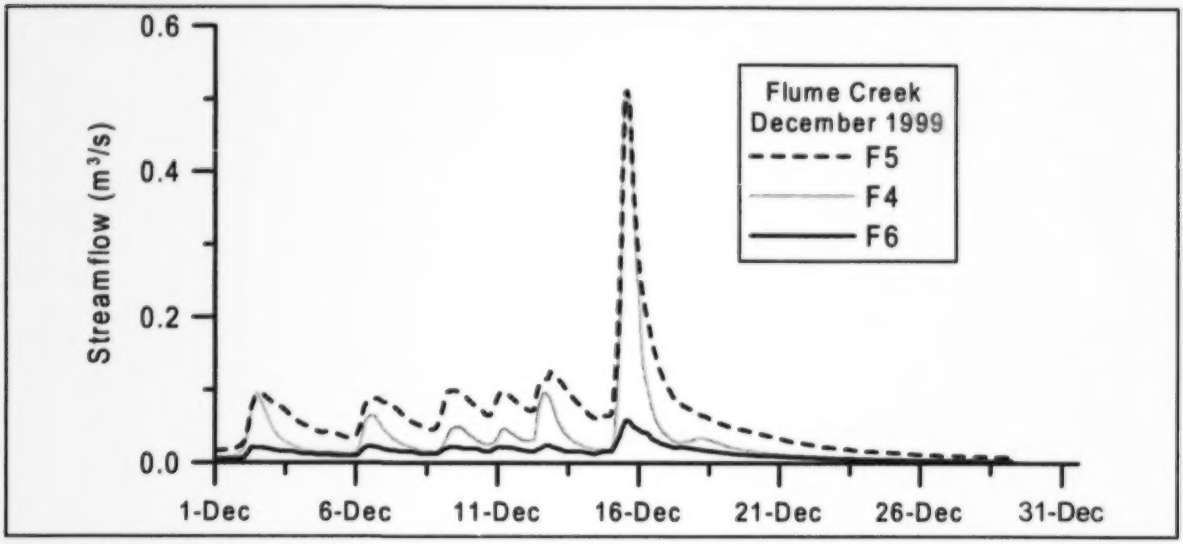

Figure 4. An example of a series of storms at Flume Creek; there are six peak flows in this sequence. The event on December 15 had a return period of 0.4 years on F6, but was increased as a result of forest harvesting on F4 and F5.

23.1 and 9.7 % of the total catchment areas of F4 and F5 respectively. After Year 2, 38.5 and 17.3 % of F4 and F5 had been harvested (Figure 3). Canopy retention was determined by measuring the reserve areas on maps and adjusting those measurements to account for blowdown. Further harvesting on F5 is expected in the year 2002, in the form of a group selection cut in the area above the existing strip shelterwood cut in the Canfor portion that will bring the harvest to about 25% of the forest canopy by watershed area. This will be followed by a second pass in the SBFEP strip shelterwood in the year 2005.

3.3 DATA ANALYSIS

The analysis followed the classic paired watershed approach, involving comparison of paired peak flows in the treatment creeks with those of the control creek before and after treatment, in order to detect changes in peak flow that are attributable to logging.

A peak flow is defined as the maximum instantaneous flow that resulted from an individual storm (Figure 4). Paired peak flows are defined as peak flows on the control creek (F6) and one or both of the treatment creeks (F4 or F5) that occur in response to the same storm event. Typically, F4 is the first to peak, followed by F5, with F6 experiencing a slightly delayed peak relative to F4 and F5. These differences in timing of peak flow are caused by differences in elevation range and channel gradient between the catchments.

The data set consisted of 34 paired events for the pre-treatment period on F5, and 25 on F4. For the post treatment period there were 40 paired events on F5 and 39 on F4, among three water years. Because streamflow data tends not to be normally distributed, both Jones and Grant (1997) and Thomas and Megahan (1998) recommend using a logarithmic transformation applied to the peak flows on both treatment and control creeks. As a preliminary test of normality, peak flows on treatment creeks

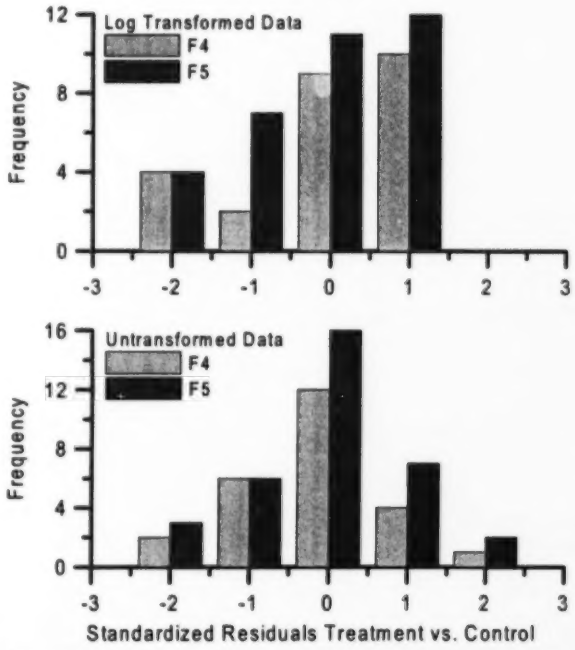

Figure 5. Histogram of residuals from regressions of peak flows on F4 and F5 vs. F6. The residuals from the untransformed regression are normally distributed, but the residuals from log transformed data are skewed, indicating that the untransformed model is the correct one.

were regressed against peak flows on the control creek, using both log transformed and untransformed data. The residuals were then analysed for normality (Figure 5). In this case the

Table 1. Regression comparisons between pre-treatment and treatment period regression equations of peak flows on F4 and F5 vs. those on F6. C = colinear, P = parallel, N = significantly different equations.

Period	Regression Comparisons F4 vs. F6			Regression Comparisons F5 vs. F6		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Pre-treatment	C	N	P	P	N	N
Treatment Year 1		N	C		N	C
Treatment Year 2			C			C

Table 2. Coefficients of regression equations of the form $PF_{treat} = b_1 PF_{control}$ where PF_{treat} and $PF_{control}$ are the peak flows on the treatment and control catchments in m^3/s and b_1 is the slope of the relationship. Note that in each case, the intercept (the b_0 term in a simple linear equation) was insignificant, and therefore is set to zero in the regression analysis.

Period	F4 vs. F6			F5 vs. F6		
	b_1	s.e.	R^2	b_1	s.e.	R^2
Pre-treatment	2.53	0.0249	92.8	3.28	0.0358	94.1
Treatment Year 1	2.82	0.0770	82.9	5.40	0.0704	95.4
Post-treatment	5.37	0.0678	83.0	6.60	0.0496	93.2

residuals from the untransformed regression were normally distributed, whereas the residuals from the transformed regression were skewed. This indicated that the log transformation is not appropriate in this case.

Peak flows on F5 and F4 were regressed against paired peak flows on F6 for the pre-treatment period and each of the post-treatment years. This resulted in four equations relating peak flows on each of F4 and F5 as a function of peak flows on F6. As a preliminary test for logging related effects on peak flow, regression comparison analysis (Kozak, 1970) was used to determine if regression equations for the different periods on F4 and F5 were significantly different, parallel or colinear. Results of this analysis are summarized in Table 1.

For the purpose of classifying peak flows according to size, a flow frequency analysis was conducted on peak flows from F6. The length of record is six years; Linsley et al. (1982) recommend using Weibull's return interval, which gives the largest peak flow (0.117 m^3/s on November 24 1998) a return interval of seven years, and defines the 0.5 year flow at 0.061 m^3/s.

Statistical analysis was done with Minitab statistical software package (Minitab Inc., 1995), with the exception of the regression comparison analysis, which was done with RegComp (Hungarian Quality Software, Inc., 1992).

4.0 RESULTS

In both treatments, regression equations for the pre-treatment period were significantly different from those of Years 2 and 3, and regression equations for Year 1 were significantly different from those of Year 2. The regression lines for Years 2 and 3 were found to be colinear; thus, Years 2 and 3 were combined

Table 3. Peak flows affected by forest harvesting. The table includes observed peak flows on the treatment and control creeks, and the flow predicted for the treatment creek by the pre-treatment equation. The percentage increase is calculated as

$$\frac{PF_{observed} - PF_{predicted}}{PF_{predicted}} \times 100$$

3a. Strip shelterwood (F5):

Storm Date	$PF_{control}$	$PF_{observed}$	$PF_{predicted}$	Percent	Event
Treatment Yr 1	F6 (m^3/s)	F5 (m^3/s)	F5 (m^3/s)	Increase	Class
11/12/98	0.021	0.187	0.069	170.2	small
11/14/98	0.079	0.495	0.260	89.9	large
11/16/98	0.064	0.295	0.211	39.6	large
11/23/98	0.055	0.346	0.179	93.2	large
11/24/98	0.117	0.749	0.384	95.2	large
12/11/98	0.103	0.608	0.337	80.8	large
12/28/98	0.041	0.265	0.134	96.8	large
01/13/99	0.048	0.243	0.156	55.5	large
01/17/99	0.041	0.229	0.135	69.3	large
01/28/99	0.091	0.520	0.299	73.9	large
Post-treatment					
11/08/99	0.067	0.494	0.220	124.9	large
12/15/99	0.059	0.512	0.195	163.1	large
12/27/00	0.027	0.158	0.087	81.7	large

3b. VR treatment (F4)

Storm Date	$PF_{control}$	$PF_{observed}$	$PF_{predicted}$	Percent	Event
Treatment Yr 1	F6 (m^3/s)	F4 (m^3/s)	F4 (m^3/s)	Increase	Class
11/05/98	0.008	0.142	0.020	619.1	small
11/12/98	0.021	0.216	0.053	305.4	large
11/14/98	0.079	0.406	0.201	102.3	large
11/23/98	0.055	0.250	0.138	81.1	large
12/28/98	0.041	0.161	0.104	54.8	large
02/05/99	0.048	0.067	0.121	decrease	small
03/03/99	0.055	0.032	0.139	decrease	small
Post-treatment					
11/08/99	0.067	0.310	0.170	82.8	large
12/15/99	0.059	0.505	0.150	236.3	large
10/20/00	0.007	0.097	0.018	435.6	small
11/26/00	0.009	0.084	0.024	252.3	small
12/27/00	0.027	0.139	0.067	106.8	small
01/05/01	0.025	0.229	0.063	263.2	large

Table 4. Summary of changes in peak flow due to forest harvesting.

Treatment type and Period	Canopy Removal (%)	Mean % Increase in Peak Flow		Percentage of Flows Affected by Logging	
		All Flows	Large Flows	All Flows	Large Flows
Strip Shelterwood Year 1	9.7	86.4	77.1	48	82
Strip Shelterwood Year 2-3	17.3	123.2	123.2	16	100
VR Year 1	23.1	232.5	135.0	35	50
VR Year 2-3	38.5	229.5	194.0	32	100

and the regression analysis redone on the combined data. Even though the regressions for the pre-treatment period and Year 1 on F4 were found to be colinear, the corresponding equations for F5 were parallel, but had significantly different intercepts. This was considered sufficient to define three distinct periods on both treatment creeks: the pre-treatment period from 1995 to the spring of 1998; the 1998-99 water year representing partial treatment; and the post-treatment period starting in the fall of 1999. Thus, there were three regression equations for each of F4 and F5 (Table 2).

For each of F4 and F5, the peak flows were plotted against the paired peak on F6 (Figure 6). A 95% prediction interval was calculated for the pre-treatment regression, and any peak flow from either treatment or post-treatment period that fell above the upper prediction line was deemed to have been increased by harvesting. Then, the percentage difference between the observed peak flow and the peak flow predicted by the pre-treatment regression equation was calculated for affected flows (Table 3).

Peak flows on F5 were more consistently affected by logging than peak flows on F4. This is because there is greater variability among the peak flows on F4 as a function of those on F6, for all three time periods (Table 4). However, the magnitude of the change in peak flow on F5 is less. As expected, there is an inverse relationship between the size of the peak flow and the percentage change in that peak flow due to logging, thus the magnitude of the increases tend to be amplified by including the smallest events. For this reason, the affected peak flows were divided into two groups, according to the return interval of the flow on F6. Large peaks were defined as peak flows with an expected return interval of greater than 0.5 years, and small peaks are those of lesser return intervals. The 0.5-year peak flow on F6 has a discharge of 0.061 m^3/s; using the pre-treatment regression equations, any peak flows of greater than 0.196 m^3/s on F5 or 0.152 m^3/s on F4 were treated as large peaks. Thus, the class of large events includes those flows on F4 or F5 for which the flows on F6 are less than the 0.5-year event, but have had their peak flows increased to above the expected 0.5-year flow by logging.

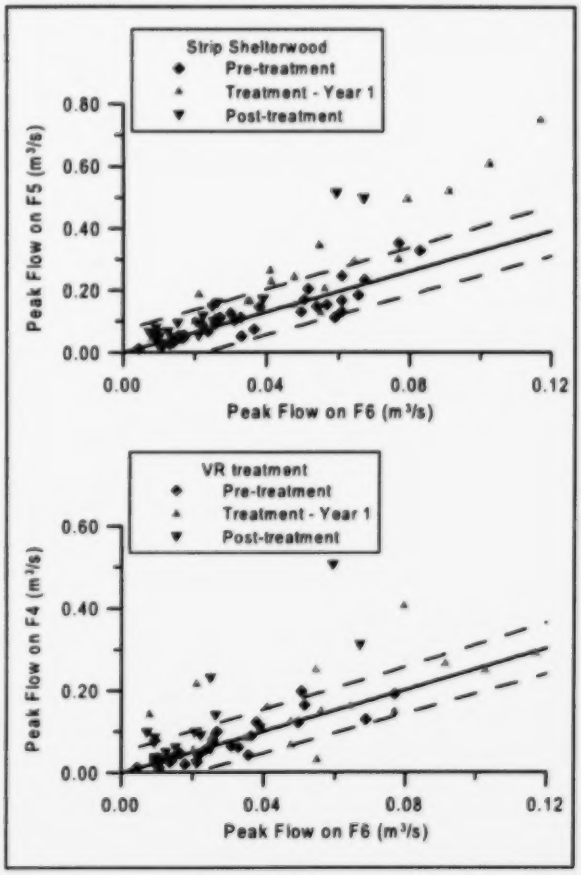

Figure 6. Paired peak flows on treated catchments F4 (lower graph) and F5 (upper graph) compared to unlogged control F6. Solid lines are the pre-treatment regressions; dashed lines represent the 95% prediction interval.

Results show that the large events are more likely to be affected by logging, but the variability and the average magnitude of the increase is less than for all affected events without regard for the return interval (Table 4). As the canopy removal increases, the variability (Figure 7a) and magnitude (Figure 7b) of the peak flow effect also increases for large events. The averaged percent increase in peak flow suggests a single relationship between peak flow increase and canopy removal regardless of the type of treatment. In an attempt to distinguish between treatments, a two-way ANOVA was performed on the data, with the percent increase as the response variable, using the two treatments (VR vs. strip shelterwood) at two levels representing treatment and post-treatment periods. The ANOVA identified the treatment as significant and the level as not significant; however, this is not conclusive since the levels of canopy removal within each treatment were not comparable. While there is no statistical basis to conclude that there is a difference between treatments, there is a physical basis to support such a distinction.

5.0 DISCUSSION

Results clearly show a much greater variability in peak flow effect in the VR treatment as compared to the strip shelterwood. The strip shelterwood is much more consistently affected by logging than the VR, but at a lower percentage of the expected peak. In the VR, sometimes the peak is lower or unaffected, but when there is an increase due to logging it is large. This variability is very likely due to the large variability in ROS conditions as noted by Harr (1986).

Based on research results from the H.J Andrews watershed in the Oregon Cascades, Harr described two scenarios whereby forest harvesting resulted in reduced peak flows. In the case of snow turning to rain, in the mature forest the canopy catches the snow, whereas in the clear-cut, the snow accumulates on the ground to form a snowpack. When the precipitation turns to rain, the snow in the canopy is melted to increase the water delivery to the soil. However, in the clear-cut the snowpack initially absorbs the rainfall, delaying water yield to the soil until the snowpack is primed. In the case of rain turning to snow, the canopy initially melts the snow, and the melt drips to the ground thereby extending the effective rainfall, while in the clear-cut, the snow begins to accumulate on the ground. On the other hand, a warm rain on a deep ripe snowpack will tend to result in a large increase in peak flow in the clear-cut because of the increased convective and latent heat transfers that are known to result from clear-cut harvesting. Harr also points out that these latter events tend to be the biggest events, and the former two types are generally of relatively minor importance.

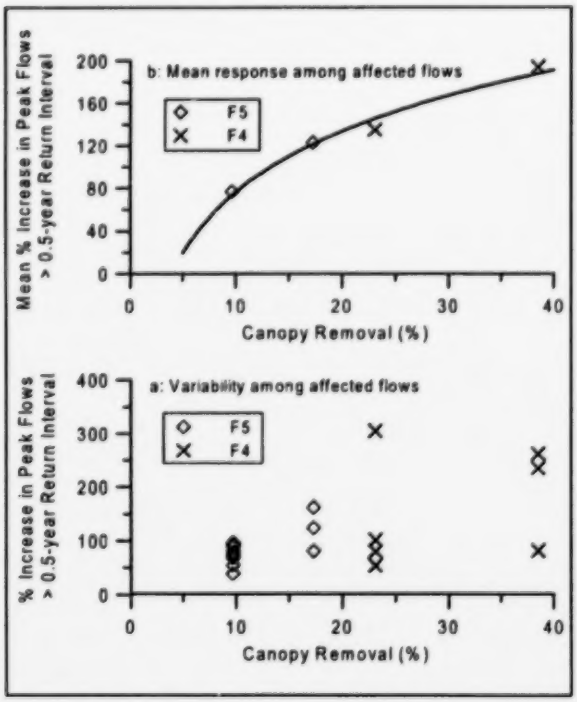

Figure 7: Percentage increase in large peak flows as a result of forest harvesting, as a function of canopy removal on F4 and F5 catchments. The lower graph (a) illustrates the greater variability in the response due to the VR treatment on F4. The upper graph (b) suggests a logarithmic relationship between mean response and the percentage canopy removal.

Observations show that the VR treatment often develops a snow pack when there is none under the mature unharvested canopy. The peak flows that occurred on F4 as a result of storms on December 15, 1999 (peak flow of 0.505 m3/s, for a 247% increase over expected) and January 5, 2001 (peak flow of 0.229 m3/s, for a 289% increase over expected) are known to have been ROS events. On the other hand, events where logging apparently resulted in a significant decrease in peak flow on F4 (February 5, 1999 and January 16, 2000) had return intervals of less than 0.5 years, and thus were less important events hydrologically.

Early season peak flows are also affected by logging on both F4 and F5. This is a result of wetter soil conditions due to reduced evapotranspiration following harvesting. The magnitude of the change is greater on F4 than on F5 because of the greater proportion of the forest canopy removed under the VR treatment compared with the strip shelterwood. Once again, these flows are less than 0.5-year events, and thus they are hydrologically less significant than the larger flows.

While the VR treatment on F4 is not sufficiently large in area to develop the full characteristics of a clear-cut, it seems clear that it is influencing the snow hydrology of the site enough that it is behaving differently from the other catchments. While snow has also been observed in the cut strips of the strip shelterwood treatment, it is strongly influenced by the forest edges. Snowpacks develop only in the middle of the strips, and therefore the snowpack in F5 is highly discontinuous compared with that of F4. Thus, the forest edge effect appears to control ROS conditions in the strip shelterwood treatment, thereby reducing the variability and magnitude of the increases in peak flow. The increased variability in the post-treatment period (Figure 5a) most likely reflects the fact that the lower strip which was harvested in 1999 is larger (i.e., both wider and longer) than the other strips.

6.0 CONCLUSIONS

The effect of two partial logging systems on peak flows in small creeks has been investigated in the Roberts Creek Study Forest. Two partial logging systems were tested. A variable retention (VR) system, in which 18% of the canopy was retained in patches and dispersed trees, was applied to 44% of the catchment area, and a strip shelterwood with a target canopy retention of 45–50% was applied to about 32% of the catchment area.

The application of partial logging systems on small creeks has been shown to result in statistically significant increases in peak flows. The magnitude of the increase is proportional to the forest canopy removed, expressed as a percentage of the watershed area of the creek. The peak flow increases are most consistent for "large" flows above a return interval of 0.5 years. The VR treatment results in a large variability in its effect on peak flow compared with the strip shelterwood treatment. Although there is not yet enough data to show it statistically, there appears to be a difference between the two treatments that goes beyond the proportion of the canopy that was removed. The VR treat-

ment has been observed to develop rain-on-snow conditions that sometimes result in large increases in peak flow compared with both the control and the strip shelterwood treatment. The strip shelterwood is dominated by the effect of forest edges, which help to control the variability in ROS conditions.

These results provide evidence to support the use of strip shelterwood or other patch treatments as a means of mitigating against large changes in peak flow, and helping to control the variability of peak flow increases due to rain-on-snow conditions. Although the study was carried out on S6 creeks, the results are relevant to larger creeks such as S2 and S3. The primary effect of forest harvesting on peak streamflow occurs at the level of the S6 tributary creek. Increased peak flows may result in an increase in channel scour, and an increased frequency of events that are capable of transporting sediment or debris to larger creeks. The physical processes that produce peak flows are the same for large and small creeks. Therefore the results obtained from this study also apply to larger creeks, although the changes in peak flow for a given canopy removal are likely to be less for larger creeks due to desynchronization of flows from tributary creeks draining different parts of the watershed.

The Flume Creek Paired Watershed Experiment is an ongoing study. Further harvesting is expected in F5 catchment, in two stages as described under harvesting methods. This will provide additional information about the effect of incremental canopy removal on peak flows. The issue of changes in peak flows due to forest harvesting will be revisited in the future when harvesting is complete.

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